THE UPPER PALAEOZOIC ROCKS IN THE COUNTRY BETWEEN THE MANNING AND KARUAH RIVERS, NEW SOUTH WALES.

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(Plate v; two Text-figures.)

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This paper deals with certain aspects of the geology of the country lying between the Manning and Karuah rivers in New South Wales. Owing to the removal of the writer to Armidale there is little possibility of completing the investigations, which were commenced in 1937; the results obtained are therefore submitted as a contribution to the geology of a most interesting region.

The accompanying sketch-map (Plate v) is not an accurate geological map of the area, but is intended to act as a locality guide and to indicate broadly the occurrences of the principal rock types. Geological mapping had not reached the stage where definite boundaries could be drawn between the different groups of rocks.

Previous Literature.

The general problem of the stratigraphy of the Carboniferous System was reviewed by S. W. Carey and W. R. Browne (1938), who discussed the Gloucester sequence in particular; C. A. Sussmilch (1921) has also dealt with the Gloucester area. Other references to the region are contained in papers by J. E. Carne (1897), W. N. Benson (1916), S. W. Carey (1934*b*) and G. D. Osborne (1937). Dr. G. D. Osborne has been engaged for some time past in collecting data relating to the Gloucester Trough and allied structures. His earlier work on the stratigraphy and structure of the area immediately to the south is well known.

Geological Structures and Rock Distribution.

The Carboniferous and Kamilaroi strata form a synclinal structure known as the Gloucester Trough which has a generally meridional trend and extends from Gloucester to the neighbourhood of Stroud. Osborne (1937, p. 387) noted that there was a remarkable swing in the strike between Booral and Stroud.

Another syncline was described by Carey (1934*b*) from the Bullah Delah District. This has a general trend N. 27° W., and, like the Gloucester Trough, consists of Carboniferous and Kamilaroi beds. He called it the Bullah Delah Syncline.

An anticlinal structure, almost certainly affected by meridional faults, is inferred between these two down-folds.

As described elsewhere (Voisey, 1939*b*), the Devonian rocks are bounded on the north by the Manning River Fault System. They appear to be faulted against the Carboniferous in places to the south, but there may be conformity between Upper Devonian and Lower Carboniferous strata in the region lying immediately to the north of the Wang Wauk River. The boundary between the two has not been defined so far and is here indicated only tentatively.

* Work done while the writer held a Linnean Macleay Fellowship in Geology.

Devonian sediments occur also in the neighbourhood of Copeland, where, it is believed, they bear faulted relationships with the Lower Carboniferous beds.

Stratigraphy.

Kamilaroi.

The Gloucester Coal Measures.

Shales, sandstones, grits, conglomerates and coal seams, totalling upwards of 1000 feet in thickness, according to Sussmilch (1921, p. 250), occupy the central portion of the Gloucester Trough, and outcrop intermittently between Gloucester and Stroud. Dr. Osborne (verbal communication, and 1937, map facing page 390) noted the presence of basalt in the Kamilaroi sequence. *Glossopteris* and petrified wood occur abundantly throughout the beds.

While little evidence is available, it would seem that, as pointed out by Sussmilch (1921), the Gloucester Coal Measures are the equivalents of the Upper or Newcastle Coal Measures.

The basal Kamilaroi conglomerates appear to have been deposited directly upon the Gloucester Rhyolites at the top of the Carboniferous sequence. The possibility that strike faults separate the two groups of rocks cannot be eliminated without detailed examination of the contact. It can only be stated that the writer, wherever he has examined the junction on the eastern and western limbs of the syncline, observed the same general sequence from lavas to conglomerate without any evidence of faulting. Moreover, no other worker has produced evidence of the presence of major faults there.

Certain important issues arise if it is accepted that the conglomerates were deposited upon the lavas. So important are these that any further information relating to this junction should be recorded.

If the Gloucester Coal Measures are the equivalents of the Upper Coal Measures, the question arises as to what was happening in the Gloucester District during the remainder of Kamilaroi time. Either there was deposition of sediments which were removed before the Gloucester Coal Measures were laid down, or the Carboniferous beds must have formed a land surface which underwent some erosion. If the second alternative is accepted there is quite sufficient explanation for the apparent absence of the well developed glacial beds in the Upper Kuttung Series.

Bullah Delah Beds.

Osborne's map (1929, p. 457) showed Kamilaroi sediments in the neighbourhood of Bullah Delah. Carey (1934) mentioned the occurrence of Upper Marine fossils within the village, preserved in a fine-grained tuffaceous sandstone. He stated further that the Greta Coal Measures were indicated by coal outcrops in portions 119 and 67, Parish of Bullah Delah, and that *Gangamopteris* was collected from shales associated with the former outcrop. No Lower Marine beds were found by him or by the writer. It would appear that the series is overlapped by the Greta Coal Measures in this locality as it is at places in the Hunter Valley.

Carboniferous.

A. Stratigraphical Sections, etc.

Barrington Section.

C. A. Sussmilch (1921, p. 242) measured a section from Barrington–Copeland Road to the trigonometrical station on The Gloucester Buckets and then easterly across the syncline. From this he calculated a thickness of 12,410 feet of Carboniferous beds.

Another interpretation of the general sequence, based on a reconnaissance traverse by Dr. W. R. Browne and the present writer, was given by Carey and Browne (1938, p. 597). These writers limited the Upper Burindi Series to the beds between the base of the lowest lava flow and the top of the highest bed containing marine fossils. Their interpretation, apart from the question of the separation of the Carboniferous series on different grounds from those used by Sussmilch, added a lava flow between the *Productus barringtonensis* bed and the Plant beds. Carey and Browne took the view also that the Conglomerates and *Rhacopteris* beds were considerably thicker than indicated by Sussmilch. In addition, Browne identified varve shales in the sub-Gloucester Rhyolite beds of the Cut Hill section.

Carey and Browne (1938, p. 597) pointed out that the lava flow taken by them as the base of the Upper Burindi (= Lower Kuttung) Series marked a change from the compact bluish-green Burindi rock types to the light-coloured tuffs which characterize the Kuttung Series in other areas. The flow itself cannot be used safely as the marker bed since, at the present time, its continuity cannot be guaranteed. However, it was traced through a distance of about four miles by the writer. In the absence of more detailed information it serves the useful purpose of allowing an approximate division to be made between the two series.

Separation of Upper Kuttung from the Upper Burindi (= Lower Kuttung) is difficult since beds containing plant fragments occur in the marine sequence and there does not appear to be any marked lithological change. Browne and the writer, in their examination of this section, regarded some cherty beds with plants as doubtfully belonging to the Upper Kuttung (see Carey and Browne, 1938, p. 597). Following an examination of the Gap Section the present writer is now inclined to place these beds and the rhyolite above them in the Upper Burindi and to take the tuffs and their intercalated conglomerates as the basal unit of the Upper Kuttung. The implied lithological change indicated by the mention of conglomerates is not so definite as it would seem, since these form only a small fraction of the total thickness of tuff and mudstone, and are not concentrated at the base of this major unit.

McInnes's Farm Section.

The section examined by Dr. W. R. Browne and the writer runs approximately east from the Barrington–Rawdon Vale Road starting at McInnes's Farm about a quarter of a mile north of Barrington School. Road cuttings reveal rhythmically-bedded mudstones and sandy mudstones with occasional thin bands of conglomerate. Large quantities of well-preserved fossil wood, including *Lepidodendron* stems, possibly *L. Veltheimianum*, occur. Small marine gastropods and brachiopods were found in the conglomerates which are characterized by small green cherty pebbles. South of the school these beds overlie the oolitic limestone horizon. Tuffs which grade almost into breccias in places follow the plant beds and constitute what may be regarded as the topmost unit of the Lower Burindi Series.

The quartz keratophyre (No. 2 Flow of Sussmilch) then forms a low ridge. Overlying the lava are the light-coloured tuffs of the typical Kuttung type which underlie the next flow of quartz keratophyre (No. 3 Flow of Sussmilch). This is succeeded by similar tuffs and the conspicuous and important *Productus barringtonensis* bed which gives rise to a prominent ridge. The coarse tuff contains numerous specimens of the brachiopod which are exceedingly well preserved considering that the matrix is composed of large felspar and quartz

grains. The rock weathers to a brown spongy material with large cavities representing the shells of the productids which have been dissolved out. By ascending a spur east of the fossil bed one crosses a great thickness of tuffs and mudstones. Some horizons are packed with marine fossils, the following forms being collected by the writer (probably = horizon X7 of Gap Section): *Fenestella*

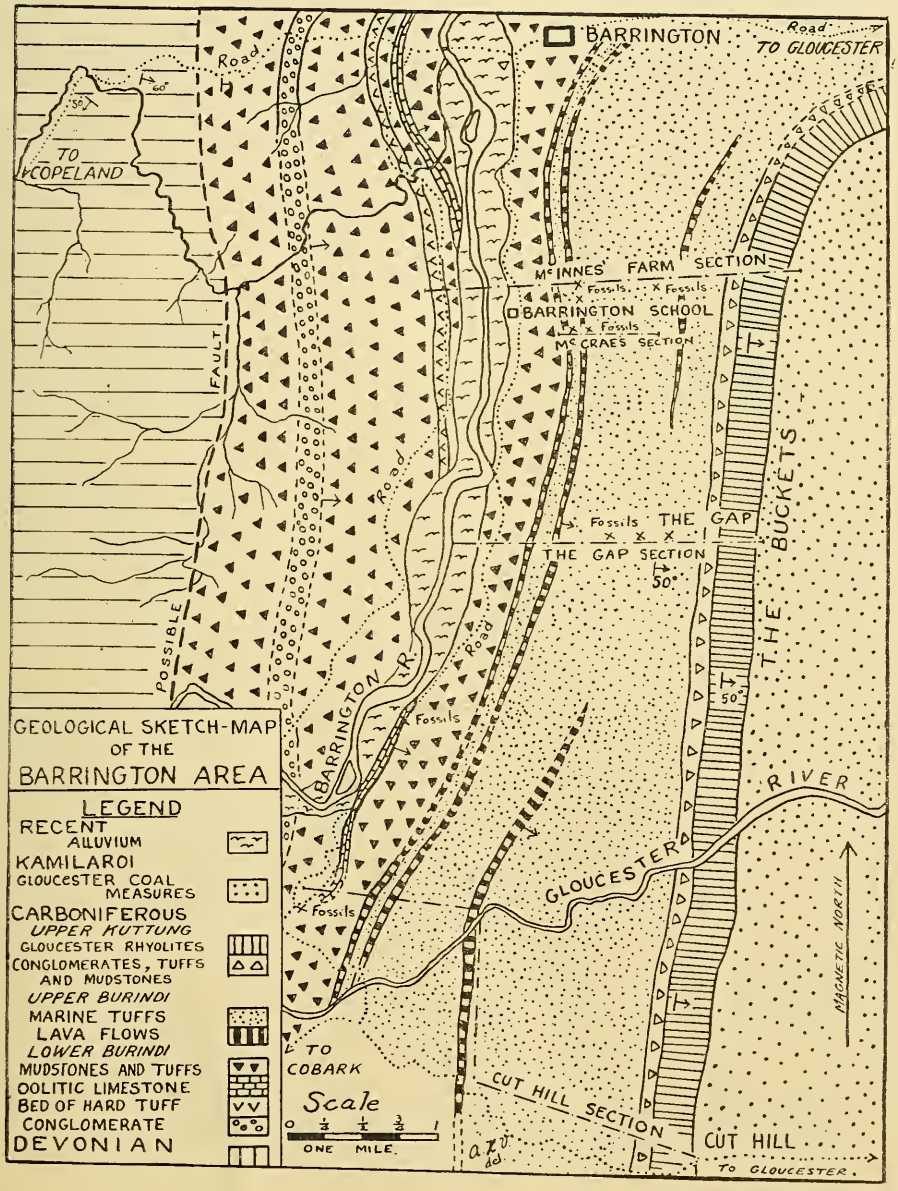

Fig. 1.

spp., abundant Crinoid stems, *Spirifer pinguis* (Sowerby), ? *Actinoconchus planosulcatus* (Phillips), *Productus pustulosus* (Phillips), *Aviculopecten flexicostatus* Mitchell, *Cordania gardneri* Mitchell, and a new genus of pelecypoda. (Specimens F38026–42, Aust. Museum Coll.)

Among these marine beds is a flow of acid lava which outcrops at the top of the main ridge. In rugged country between this and the main lava flow at the top of the Upper Kuttung sequence are tuffs, conglomerates, mudstones and cherty rocks containing plant remains. Sussmilch (1921) collected fossil plants from tuffs and shales immediately below the Gloucester Rhyolites which terminate the Upper Kuttung succession.

The section described above was not measured accurately, but the sequence is indicated in figure 2.

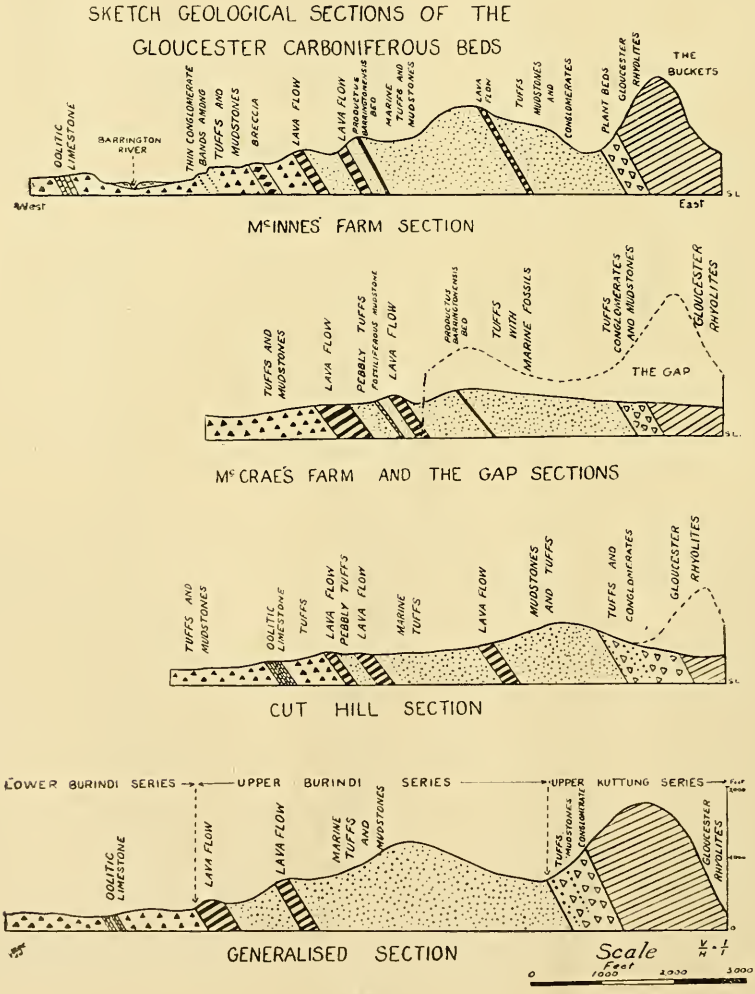

Fig. 2.

McCrae's Farm Section.

Sussmilch (1921, p. 246) mentions McCrae's Farm (Portion 4, A.A. Co.'s subdivision) as one of the places where the *Productus barringtonensis* bed outcrops. This and associated beds were traced from McInnes's Farm southward, and the following section was measured then in an easterly direction on the north side of a creek.

	Approx. Thickness. Feet.
Upper Burindi Series.	
Tuffs with marine fossils (*Productus barringtonensis* bed being included in the group)	400 plus
Lava flow (Sussmilch's No. 3 Flow)	150
Coarse, medium and fine tuffs	180
Mudstones with marine fossils (horizon W1)	10
Coarse pebbly tuffs	200
Medium textured tuffs	350
Lava flow (Sussmilch's No. 2 Flow)	400
	1,690 plus

The fossil bed, horizon W1, was found a short distance east of the ridge of lava (No. 2 Flow). The fossils contained in it include: *Productus* sp. indet., *Orthis valida* Dun, ? *Actinoconchus planosulcatus* Phillips sp., *Chonetes* sp., *Productus semireticulatus* Martin sp., *Strophomena analoga* Phillips.

The Gap Section.

A section was measured across the Upper Carboniferous strata between a point on the road on the east side of Barrington River, a mile and a half south of Barrington Public School (in the neighbourhood of portion 62, parish of Verulam) and the Gap. The traverse was made close to the present boundary fence between the properties of Messrs. H. C. Perram and G. A. Wesley.

	Approx. Thickness. Feet.
Upper Kuttung.	
The Gloucester Rhyolites	1,000 plus
Tuffs, conglomerates and mudstones	350
Upper Burindi.	
Tuffs and dark grey mudstones	500
Medium to coarse grained tuffs	50
Tuffs with abundant marine fossils (horizon X7)	300
Coarse tuffs with bands of marine fossils (horizon X6)	40
Fine-grained tuffs and mudstones (horizon X5)	140
Coarse tuffs with marine fossils (horizon X4)	80
Coarse tuffs	120
Fine-grained tuffs	70
Coarse tuffs with rounded pebbles in some bands	120
Limestone and tuff (horizon X3)	10
Coarse tuffs	450
Fine-grained tuffs with marine fossils (horizon X2)	15
Productus barringtonensis bed of coarse tuff (horizon X1)	30
Tuffs	300
Lava flow (No. 3 flow)	250
Tuffs and mudstones	200
Lava flow (No. 2 flow)	150
	4,175 plus

The outcrops of the four last-mentioned units were poor, so that the thicknesses given are not reliable. Details of this part of the sequence may be ascertained from adjacent sections, notably that of McCrae's Farm.

The *Productus barringtonensis* bed and overlying marine tuffs and mudstones here form a saddle between two much higher ridges which are partly composed of these units. The tuffs and mudstones which follow them also contain a well developed marine fauna. Collecting was done from a number of beds and the fossils are distributed as follows:

Horizon X7.—*Productus pustulosus* Phillips (abundant), *Spirifer* cf. *pinguis* Sowerby, ? *Actinoconchus planosulcatus* Phillips.

Horizon X6.—Indeterminate pelecypod, indeterminate cast of *Spirifer*.

Horizon X5.—Indeterminate brachiopod fragments, internal cast of gastropod, internal cast of *Spirifer*.

Horizon X4.—Indeterminate specimens.

Horizon X3.—*Chonetes* sp. indet.; possibly 2 species present, viz.: *Chonetes papilionacea* and *C. hardrensis*.

Horizon X2.—*Camarotoechia* cf. *pleurodon* Phillips, *Spirifer* indet. sp.

Horizon X1.—*Productus barringtonensis* Dun, *Productus* sp. indet., indeterminate pelecypod.

The tuffs vary considerably in texture, grading from mudstones into gritty rocks with large rounded pebbles in them. They are mostly, if not all, water-sorted, and in some cases could be called ordinary grits and sandstones. However, most of the beds are tuffaceous. The great number of shells present in horizon X3 has given rise to a rock which is almost wholly composed of calcium carbonate.

Above the prolific fossil horizon, Zone X7, there appears to be little change in the nature of the tuffs. Only the tuffs outcrop in the paddocks, but the creek which flows through the Gap exposes dark grey mudstones which dip generally east at 50 degrees. It is apparent that the mudstones are far more abundant in the sequence than outcrops indicate, since they are only exposed by creeks or cuttings. Their presence must be inferred among the tuffs which are listed in the section given. The section taken across Cut Hill contains more mention of the mudstones, since observations were made of the rocks in road cuttings.

Several thin bands of conglomerate consisting of well-rounded lava pebbles occur in some of the more massive tuff beds and grade into them. As in the Cut Hill sections, these units are of minor importance and do not differ greatly from the tuffs lower in the sequence which contain similar pebbles scattered more sporadically. Separation of the conglomerates and associated tuffs from the underlying beds would be arbitrary and not justified by field evidence. That some change in the nature of the sedimentation must have occurred somewhere in the sequence is indicated by the evidence supplied by Sussmilch that plant beds occur between the conglomerates and the Gloucester Rhyolites. No trace of such plant beds was found on the traverse taken—deposits of Recent breccias of rhyolite covering the rocks immediately below the lavas. Any plant beds which might be present are grouped in the thickness of 350 feet as tuffs, conglomerates and mudstones.

Cut Hill Section.

A section was measured from the Barrington–Rawdon Vale Road east through portions 117 and 86, parish of Verulam, to the Gloucester River. There an offset was made to the south and the section was continued over Cut Hill along the

Gloucester–Rawdon Vale Road to the ridge of rhyolite at the top of the Upper Kuttung sequence. The whole section corresponds with those measured near Barrington and McInnes's Farm several miles to the north.

The succession of beds in descending order is as follows:

	Approx. Thickness. Feet.
Upper Kuttung.	
The Gloucester Rhyolites	500 plus
Tuffs and mudstones (plant beds?)	500
Tuffaceous conglomerate	30
Tuffs	25
Tuffaceous conglomerate	40
Tuffs with subordinate mudstone	170
Tuffaceous conglomerate	10
Upper Burindi.	
Mudstones and subordinate tuffs	430
Tuffs	90
Tuffs and mudstones	500
Mudstones with bands of tuff	60
Greenish-grey mudstones	175
Acid lava	225
Fine-grained tuffs with cherts containing fragmental plant remains	120
Coarse tuff with marine fossils	110
Fine-grained light grey tuffs	60
Light grey tuffs with conglomerate bands	110
Gritty tuffs	100
Massive coarse tuffs with lava pebbles	60
Grey tuffs with plant remains	440
Gritty tuffs	80
Acid lava (No. 3 flow)	250
Pebbly tuffs and medium-grained tuffs	280
Acid lava (No. 2 flow)	100
Lower Burindi.	
Fine-grained tuffs with fragmental plant remains	80
Coarse tuff with well-rounded pebbles	80
Coarse felspathic tuff (marine fossils)	75
Tuffs	110
Light-coloured tuffs	40
Mudstones and tuffs (marine fossils, horizon V1)	10 plus
Fine-grained light-coloured tuffs	150
Oolitic limestone	20
Mudstones with marine fossils (horizon U1)	75
Oolitic limestone	30
Banded mudstones	5
Tuffs with conglomerate bands	50
	5,190 plus

Addition of the beds below horizon V1 was carried out with reference to a section measured about a mile north of the main traverse, approximately in portion 55, parish of Verulam.

The composite section commences with greenish-grey tuffs which are separated by thin bands of conglomerate containing small green pebbles. The beds are exposed by cuttings on the Barrington–Rawdon Vale road. They are overlain by banded mudstones and the oolitic limestones. Thinly-bedded greenish-grey mudstone with some sandy phases separates the two limestone horizons and contains the following marine fossils (horizon U1): *Chonetes aspinosa* Dun (F38755–8), *Spirifer striata* Sowerby, *Productus* cf. *pustulosus* Phillips, *Productus semireticulatus* Martin, *Spirifer pinguis* Sowerby.

The limestones contain similar fossils, not so well preserved. The green pebbles so characteristic of the conglomerate bands also occur in the calcareous rock.

Fine-grained light-coloured tuffs follow and pass into gritty tuffs. Within this unit mudstone bands containing marine fossils occur. From a road cutting on the east of the Barrington–Rawdon Vale road in the southern part of portion 117, Parish of Verulam, the following fossils were obtained (horizon V1): "*Leptaena analoga*" Phillips, *Productus* sp., *Spirifer pinguis* Sowerby, *Spirifer striata* Sowerby.

Fragments of marine fossil shells occur throughout the next few hundred feet of coarse tuffs and tuffaceous conglomerates. Plant remains occur in the tuffs below the first lava flow in the sequence. These beds closely resemble those above the lava and are unlike the Lower Burindi types. However, on the arbitrary basis of subdivision adopted for the time being, they must be retained in the lower series (because they underlie the lowest lava flow).

Following these tuffs is the Upper Burindi Series which contains coarser tuffs, passing into conglomerates in places. They are interbedded with flows of acid lava. Traces of plants and marine shells are abundant, but no well preserved fossils were found on this traverse, hence the positions of the beds in relation to the fossil zones are doubtful.

Finer grained tuffs and mudstones were met higher in the sequence.

The reappearance of conglomerate bands, much coarser than those lower down, has been taken to indicate the basal stage of the Upper Kuttung Series. Thereafter, except for a more or less well defined conglomerate band, the strata consist of tuffs and fine-grained mudstones, some of which are probably glacial in origin. The glacial rocks or varve-shales were first recognized by Browne (Carey and Browne, 1938, p. 598). The conglomerates are made up of rounded pebbles of the hard rock types set in a tuffaceous matrix. They are almost certainly the result of water-sorting and not of glacial influences. The coarse rocks are well distributed through the sequence in this section and are subordinate to the finer-grained sediments. They do not form a well defined basal unit.

At least 500 feet of acid lavas known as the Gloucester Rhyolites terminate the Carboniferous section. The variation in the thickness of this unit from point to point might be due to several factors, one of which could have been erosion during early Kamilaroi times.

Nowendoc Road Section.

The McInnes's Farm and Cut Hill Sections were taken on the eastern side of the Barrington River and included only a small portion of the Lower Burindi Series. The latter, however, are well represented between Barrington and Copeland, probably being cut off by a fault on the west before giving way to Devonian beds.

The series contains a large proportion of the olive-green mudstones so typical of the Lower Burindi suites elsewhere. Hard bands of a medium to coarse tuffaceous rock separate the finer-grained crumbling sediments. One such band may be followed south for some miles on the western side of the Barrington River. It underlies the oolitic limestones and overlies similar tuffs whose outcrops may be seen running parallel to it on the western side. Outcrops of the mudstone are not good, but the Nowendoc Road exposes a fairly continuous sequence of beds commencing about half a mile from its junction with the Barrington–Copeland Road.

The following section was measured (in descending order):

	Approx. Thickness. Feet.
Olive-green mudstones	10
Grey tuffs with scattered pebbles	5
Conglomerate	20
Olive-green mudstones	40
Crinoidal limestone with mudstone bands	55
Olive-green mudstones	50
Crinoidal limestone	20
Olive-green mudstones	50
Tuffs	30
Conglomerate	15
Tuffs	10
Olive-green mudstones	30
Conglomerate	5
Olive-green mudstones	10
Conglomerate	5
Olive-green mudstones and tuffs	15
Tuffs	10
Olive-green mudstones and tuffs	40
Olive-green mudstones	10
Tuffs	40
Olive-green mudstones	10
Olive-green mudstones and tuffs	500
	980

This section is terminated by a fault which crosses the Nowendoc Road near the southern end of portion 57, Parish of Fitzroy. Devonian sediments are exposed by the road cuttings on the ridge between portions 71 and 77. Conglomerates on the road from Barrington to Copeland on a hill between portions 83 and 46 may belong to one of the beds mentioned in the above section. If this is so, some hundreds of feet of tuff lie below the conglomerates and these give way to Devonian rocks somewhere in portion 32, Parish of Fitzroy.

The nature of the junction between the Carboniferous and Devonian rocks has not been determined beyond doubt by any worker. Outcrops are discontinuous and the tuffs of the two systems, which give rise to the principal outcrops, are somewhat similar. The marked break in slope parallel to the strike of the Carboniferous rocks may be significant. Sussmilch (1921, pp. 248–249) discussed the problem, pointing out that the boundary marked on the map was approximate only. He remarked on the differences between the strikes of the two formations and on the fact that the axis of the synclinal structure containing Carboniferous and Kamilaroi rocks was opposed to the Devonian lines of folding. He suggested that these points were indirect evidence of an unconformity. Osborne (verbal communication) is of the opinion, however, that the whole sequence is conformable.

The present writer is in favour of faulting as an explanation of the discordance in strike. So many other important faults occur in this region that a major fault of this character and in this position would accord with the general fault pattern.

From the stratigraphical viewpoint it would appear that the Barraba Series of the Tamworth District is worthy of better representation than that attributed to it by Sussmilch (1921, p. 241) i.e. the beds between the six- and seven-mile posts on the Gloucester–Copeland Road. These rocks could belong to the Tamworth Series. If this is the case, either the Barraba Series has not been

developed in the area, or, as appears to be more likely, it has been faulted out of the sequence, together with some of the Lower Burindi beds. Even if the estimated thickness of 6,500 feet (Sussmilch, 1921, p. 242) is correct, and this appears to be the case, the Lower Burindi Series seems to lack certain important units. It is admitted that changes in facies might account for the differences between this section and those in neighbouring districts, such as that at O'Sullivan's Gap where a high range is composed of hard Lower Burindi strata, and that at Firefly Creek where the crinoidal limestone is prominent. Nevertheless, the writer is impressed by the apparent inadequacy of the Gloucester section and considers that the evidence, such as it is, favours a faulted junction.

Firefly Creek and Brushy Mountain.

Sussmilch (1921, pp. 243, 244) described a coarse crinoidal limestone which outcrops on the Nowendoc road. He noted that a similar limestone outcropped on the stock reserve two miles out of Gloucester and again in Tugrabakh Creek, near Brushy Mountain. The limestone on the Nowendoc Road is included in the measured section described above. The strata associated with it do not appear to correspond with those adjacent to the Brushy Mountain belt. These latter are more allied to Devonian rock-types as were those interbedded with the limestone at the quarry near Tugrabakh Creek on the Bundook road (Sussmilch, 1921, p. 240). Indeed, it would appear as if the course of Tugrabakh Creek has been determined by the presence of the limestone and its associates and that the same band runs from the Bundook road to Brushy Mountain and beyond.

Following examination of the beds mentioned above, the writer considered the Tugrabakh Creek limestone (Zone T) to be Devonian; a number of fossils collected from the neighbourhood were submitted to Dr. Dorothy Hill of the University of Queensland and Mr. H. O. Fletcher of the Australian Museum. Dr. Hill identified the following corals: *Syringopora* ? or *Cladochonus* ?; Zaphrentoid coral; *Amygdalophyllum* sp.; and *Michelinia* sp.

She suggested that the horizon might be the equivalent of the lowest of the Carboniferous limestones in the Rockhampton District of Queensland. She added that, because no columellate corals (e.g. *Amygdalophyllum*) are known from the top of the Devonian in Germany where the facies is suitable, it is reasonable to assume that the limestone is Lower Carboniferous.

Mr. Fletcher recognized *Cordania gardneri* Mitchell among crinoid stems and indeterminate gastropod remains in mudstones associated with the same limestone in the Firefly Creek area. Hence, he regards the beds as being Lower Burindi.

The Tugrabakh Creek limestone swings southward a little to the east of Brushy Mountain and can be followed from the hills to the north of the junction of Firefly Creek road and the Pacific Highway to a point where it crosses the Firefly Creek road three and a half miles from the junction. In this region it would appear as if there were two limestone horizons, but there may have been duplication by strike faulting. The strike of the bed swings round from approximately east-west to north-west–south-east.

The beds outcropping alongside the road to Bunyah include a spectacular tuffaceous conglomerate containing the remains of marine fossils. None of the fossils, which are crinoids and brachiopods, were sufficiently well preserved for identification. Associated with the conglomerate were tuffs and mudstones which could be Devonian or Lower Carboniferous in age. It is suggested, on account of the presence of the marine fossils and the variation in rock type, that the beds are Lower Carboniferous rather than Upper Devonian. However, no

unconformity or sudden lithological change was observed when the beds were crossed between Krambach and Bunyah and it would appear as if the Devonian beds pass upwards into the Carboniferous without much variation.*

Even if he accepts the correlation between the Tugrabakh Creek limestone and that on the Nowendoc Road, the writer finds it still more difficult to believe that the big thickness of beds examined in the Krambach-Bunyah district could be represented by those between Barrington and Copeland. Hence, there might here be further evidence for the alleged fault between the Carboniferous and Devonian beds in that area.

Rawdon Vale and Cobark.

Mr. Fordyce, who recently retired from the position of Shire Engineer at Gloucester, showed the writer some marine fossils of Lower Burindi age which he had obtained from the following localities: (*a*) portion 76, Parish of Barrington; (*b*) portions 44 and 31, Parish of Barrington. He stated that similar fossils were plentiful in the country about Cobark and Rawdon Vale and mentioned also fossils which were found in the neighbourhood of Berrico Mountain.

Such occurrences are of importance, particularly as some are from the west of Copeland, indicating that the outcrops of Devonian rocks are limited in a westerly direction. It would be interesting to determine whether the block so formed is entirely surrounded by faults as is the Devonian occurrence between Tinonee and Wallaby Point. The faults are believed to occur on at least three sides. (See accompanying map, Plate v.)

Booloombayt Section.

Road cuttings in a hill about four miles north of Bullah Delah towards O'Sullivan's Gap reveal very interesting Carboniferous rocks. The strata strike from northerly to north-westerly and have a very steep dip which is generally westwards or vertical. Since the beds lie on the eastern limb of the Bullah Delah Syncline it is assumed that the strata are older as one goes east or north-east. If this is so, the section measured is in descending order as follows:

	Feet.
Tuffs with thin bands of micaceous rock	100
Hard black mudstones with marine fossils	220
Grey mudstones with marine fossils	240
Productus barringtonensis bed	5
Light-coloured coarse tuffs	200
Light-grey crumbling mudstone	40
Coarse dacitic tuff containing large boulders of dacitic lava	50
Dacite?	10
Conglomerate with tuffaceous matrix containing lava boulders up to 3 feet across	20
Dacite?	20
Conglomerate with tuffaceous matrix, containing large lava boulders	50
Fine grey tuff	25
Conglomerate with tuffaceous matrix	30
	1,010

The fossils identified from the beds at the top of the sequence are *Spirifer* sp. indet., *Chonetes* cf. *hardrensis* Phillips (Australian Museum Collection, Nos. F38760–74).

The *Productus barringtonensis* (Dun), (Aust. Mus. Coll., F38759) and the lavas indicate that the beds are Upper Burindi in age and this is further suggested by

* See note to map; p. 210.

the occurrence of Lower Burindi strata lower down on the eastern limb of the Bullah Delah Syncline at O'Sullivan's Gap.

The interesting occurrence of tuffs, lavas and tuffaceous conglomerates is excellently exposed and is worthy of more detailed petrological treatment than the hurried examination which was given it.

O'Sullivan's Gap Section.

Carboniferous rocks occupy most of the area between the Myall and Wang Wauk Rivers and the Lower Burindi beds are the most widespread and conspicuous. The Lower Burindi strata comprise the principal part of a high range which forms the divide between the two rivers. The beds here probably lie on the eastern limb of the Bullah Delah Syncline, and dip consistently with such a view. However, it is probable that some faulting has occurred between them and Bullah Delah, since the high dips noted would give a very great thickness to the Upper Burindi and/or Upper Kuttung beds in an unbroken sequence.

The Gloucester–Nabiac road crosses the range at O'Sullivan's Gap and road cuttings reveal the strata particularly well. The beds dip generally south-westerly at 45°–65°. The following section (in descending order) was measured by compass and pacing traverse on the southern side of the hill:

	Approx. Thickness. Feet.
Black cherty mudstone	40
Light-coloured tuff	5
Black cherty mudstone	15
Light-coloured tuffs and mudstones	12
Micaceous rock	8
Light grey mudstones	50
Black chert	3
Light grey mudstones and tuffs	12
Tuff resembling dacite	50
Tuffaceous agglomerate	40
Black chert	60
Tuffs, etc.	30
Dacite (?)	10
Tuffs and mudstones	5
Dacite (?) and agglomerate	100
Mudstones and tuffs	300
Black mudstones	200
Grey mudstones with micaceous bands	450
Hard black cherty mudstones	15
Light grey mudstones	80
Hard mudstones and soft grey mudstones	60
Micaceous rock	5
Crumbling mudstones	100
Hard black mudstones	200
Grey mudstones	30
Hard black mudstones (Gastropod horizon)	10
Micaceous rock	5
Black mudstone	60
Grey mudstone and micaceous rock	4
Black mudstone with subordinate light grey mudstones	200
Black mudstones (*Spirifer* horizon)	30
Bluish green cherty tuffs	20
Hard blue tuffs with plant fragments	10
Black cherty mudstone	20
Massive tuffs with interbedded mudstones	100 plus
Total thickness measured	2,339 feet

The above section was underlain by a big thickness of massive tuffs with subordinate interbedded mudstones. The bends in the road prevented further measurement being made satisfactorily, and exposures on the hillsides were poor.

It would appear from the presence of the acid lavas at the top of the sequence that these beds could be included in the Upper Burindi suite. Insufficient work was done to enable a satisfactory basis of division to be made in the area.

The mudstones which make up a large part of the sequence are typically those of Lower Burindi sequences at Dungog and at Hilldale. From the last-named locality Osborne (1922) records cherty mudstones, tuffs and mica-bearing rocks which correspond closely to those in the O'Sullivan's Gap section. The micaceous rocks are also found at Kolodong near Taree in the Lower Burindi Series (Voisey, 1938).

Perhaps the most conspicuous feature of the sequence is the rhythmical bedding of the mudstones. The rocks vary slightly in their characteristics and somewhat different adjectives have been used to describe the fine-grained sediments. The mudstones range in colour from light grey to black, and frequently have a greenish tinge. They possess different textures from bed to bed and also differ in hardness. Some are almost cherts.

The tuffs are generally fine-grained and occur in beds several feet in thickness, being thicker and more massive lower down in the sequence than in the portion measured.

The rock which has been termed a dacite has not been examined petrologically since the study of the volcanic rocks of this and the Booloombayt section is deserving of detailed treatment. It is hoped that a petrologist will undertake this work and that an attempt will be made to correlate the lavas with those in the Clarencetown-Paterson District.

The Spirifer horizon contains the following fossils: *Spirifer pinguis* Sowerby, *Spirifer striata* Sowerby, Crinoid stems, *Chonetes* cf. *hardrensis* Phillips, "*Leptaena analoga*" Phillips, *Fenestella* sp., *Productus* sp.

Mograni Section.

Between Mograni Creek and Mograni Mountain good exposures of Carboniferous rocks were examined. Crinoid stems and abundant but fragmental marine fossils were found.

The section measured (in descending order) was taken about a mile and a half east of the junction of the Mograni Road and the Pacific Highway.

	Approx. Thickness. Feet.
Acid lava	80
Soft grey mudstones	110
Grey chert	40
Cherts and mudstones	30
Felsite	60
Soft mudstone	60
Banded rhyolite	110
Mudstone	200
Felsite	5
Mudstone	40
Acid lava	200
Coarse tuffs	160
Banded rhyolite with botryoidal structures	150
Coarse tuffs	200
Dark blue coarse tuffs	500
Gritty tuffs with marine fossils	50
Mudstones and tuffs	(not determined)
Total measured thickness	1,995 plus

Sussmilch (1921, Plate xviii) placed a probable fault between the sediments measured and the main volcanic beds of Mograni Mountain, evidently having noted the discordant dips of the strata mentioned above. These dips are principally vertical or to the north, and overturning is indicated.

The fault which he indicates near Mograni Cutting has been confirmed and extended further to the east and to the west.

The exact position of the sequence in the Carboniferous succession has not been worked out.

Wauk Ivory.

On the eastern side of the Gloucester Trough, Carboniferous beds outcrop in fairly rugged country north and south of the Wauk Ivory road. No sections were measured here, but a reconnaissance trip revealed essentially the same sequence as on the western limb.

Marine fossils were found in loose material beside the Wauk Ivory road by the writer, but Mr. Fordyce reported marine fossils *in situ* on portions 211 and 216 of the A.A. Company's Subdivision close to the same road.

Lower Burindi rocks appear to continue for some distance to the south-east beside the track to Upper Myall. The route is just trafficable for a motor vehicle with a high clearance, and rock outcrops for the most part are poor. Most of the sediments seen consisted of tuffs and mudstones. Some of the latter were olive-green in colour and contained bands of intraformational breccias. Near the eastern boundary of the A.A. Company's land the strikes were nearly east and west.

About 23 miles from Gloucester carbonaceous shales and impure coal seams were found associated with light-coloured tuffs. They suggested either an Upper Kuttung or Kamilaroi age for the occurrence. Five miles further on, towards Upper Myall, hills containing a spectacular tuffaceous conglomerate were observed lying to the south of the road. It is believed that these represent outcrops of Wallarobba Conglomerate, but no confirmatory mapping was done.

The road was then followed through the centre of the Bullah Delah Syncline to the village of Bullah Delah.

Myall Lakes.

Carey (1934*b*) examined the Carboniferous beds around the Myall Lakes and concluded that only the glacial stage of the Kuttung Series was developed. He gave a thickness of 6,500 feet to this stage. He calculated a thickness of 25,000 feet for the "Burindi" Series (i.e. Upper and Lower Burindi).

Only the Lower and possibly some of the Upper Burindi beds were examined by the writer along the northern shores of Myall and Smith's Lakes. Lower Burindi beds, probably a continuation of those at O'Sullivan's Gap, were crossed before Mayer's Flat was reached. Conglomerates are conspicuous in association with tuffs between here and Bungwahl. According to Carey (1934*b*, p. 42), an anticlinal axis occurs at Bibby Harbour on the south side of the lake. This does not appear to continue on the northern side, since the dip from Mayer's Flat to Bungwahl appears to be consistently to the south-west. At Bungwahl mudstones containing marine fossils dip in a direction 250 degrees at 20°.

On the northern side of Smith's Lake, three miles from Bungwahl, the dip is 220 degrees at 60°.

From Elizabeth Bay rhythmically-bedded mudstones and tuffs dipping generally south-west are seen in the adjacent headlands.

An interesting tuffaceous conglomerate occurs near the Elizabeth Bay turnoff beside Lake Forster. The position of this in the sequence was not determined.

Forster.

Carboniferous strata are responsible for the formation of Cape Hawke, Bennett's Head, and the hills near Forster.

J. E. Carne (1896) recorded fossils from near the Signal Station at Forster, which were identified by W. S. Dun as follows: *Chonetes* sp. (closely allied to *C. hardrensis*), *Productus semireticulatus* Martin, *Spirifera*, *Gosseletina australis* Eth. fil., *Fenestella*, *Orthoceras*, corals (dendroid branching forms), *Bellerophon*, *Entolium* ?, Knorria.

Cyrtina carbonaria var. *australasica* Eth. fil. had already been recorded by Mr. Etheridge.

The writer independently came upon what was probably the same locality on the eastern end of the headland and collected the following forms: *Chonetes* sp. cf. *C. hardrensis* Phillips, *Productus* sp. cf. *semireticulatus* Martin, *Pelecypod* indet., *Monilopora nicholsoni*, *Calamites* (Australian Museum Collection, Nos. F38101–6; F38115–7; F38064).

Mr. Fletcher, who identified the fossils, suggested that they might be Upper Carboniferous, but the sediments in which they occur are fine-grained tuffs and mudstones which are more characteristic of the Lower Burindi Series.

B. SUMMARY OF THE CARBONIFEROUS SEQUENCE.

Further detailed mapping must be done before an accurate sequence for the Carboniferous beds is obtained. In the meantime, however, a tentative generalized section is submitted as follows:

	Max. Thickness. Feet.
Upper Kuttung Series.	
The Gloucester Rhyolites	1,500
Tuffs and mudstones with occasional conglomerate bands (Zone Y)	800
Upper Burindi (= Lower Kuttung) Series.	
Mudstones and tuffs with abundant marine fossils in some bands (Zone X)	3,000
Lava flow	250
Tuffs (Zone W)	800
Lava flow	400
Lower Burindi Series.	
Marine mudstones and tuffs with thin bands of conglomerate (Zone V)	1,000
Oolitic limestone	20
Marine mudstones (Zone U)	80
Oolitic limestone	30
Marine mudstones and tuffs with subordinate limestones and conglomerates	6,000
Tugrabakh Creek crinoidal limestone (Zone T)	200
Marine mudstones, tuffs and conglomerates	500
Total	14,580 plus

It will be seen that, in general, this sequence is in accord with that given by Sussmilch (1921, p. 242). In dividing it into three series, the writer has followed the lead of Carey and Browne (1938, p. 597).

The No. 1 lava flow has been omitted because it was not observed in any other of the sections examined and because severe faulting is known to occur to the east of Barrington where Sussmilch observed this flow. Other lava flows occur at various places in the sequence, but, since they are discontinuous, they may be disregarded for the time being. That they are present in abundance is indicated by the sequence in the Mograni sector. In dealing with individual sections, the No. 2 and No. 3 lava flows mentioned by Sussmilch are given these numbers since they are continuous for some distance and are indicated on his map.

The mudstones, tuffs, conglomerates and limestones which comprise the greater part of the Lower Burindi Series have been grouped together and an estimated thickness of 6000 feet has been assigned to them. In this group are included the O'Sullivan's Gap, Forster, Dungog and other beds.

The Tugrabakh Creek crinoidal limestone is mentioned, since it probably occurs near the base of the Lower Burindi Series. Since the junction between Carboniferous and Devonian beds has not been decided upon, the exact thickness of beds below the limestone and above the Barraba Series is not known.

C. PALAEONTOLOGY.

Fossil collecting in the area has been done hurriedly in every instance so that few generalizations with regard to the faunal distribution are justified at the moment. The lists of forms collected to date are as follows:

Upper Kuttung Series.

Zone Y.

Sussmilch collected: *Rhacopteris intermedia*, (?) *Rhacopteris ovata*, *Cardiopteris polymorpha*, *Archaeopteris* sp. ind., Calamitean stems.

Upper Burindi (= Lower Kuttung) Series.

Zone X.

Fenestella spp., Crinoid stems, *Spirifer pinguis* Sowerby, *Chonetes* cf. *papilionacea*, *Chonetes* cf. *hardrensis*, *Camarotoechia* cf. *pleurodon* Phillips, *Actinoconchus planosulcatus* Phillips, *Productus pustulosus* Phillips, *Productus barringtonensis* Dun, *Productus* sp. indet., *Spirifer* sp. indet., *Aviculopecten flexicostatus* Mitchell, indeterminate pelecypod, *Cordania gardneri* Mitchell.

At the top of the zone is a bed which contains a great abundance of *Productus pustulosus*, while the lowest bed is the prolific *Productus barringtonensis* horizon.

Zone W.

Orthis valida Dun, *Chonetes* sp., *Productus semireticulatus* Martin sp., *Productus* sp. indet., *Strophomena analoga* Phillips, ? *Actinoconchus planosulcatus* Martin sp.

Lower Burindi Series.

Zone V.

"*Leptaena analoga*" Phillips, *Productus* sp., *Spirifer pinguis* Sowerby, *Spirifer striata* Sowerby.

Zone U.

Chonetes aspinosa Dun, *Productus pustulosus* Martin, *Productus semireticulatus* Martin sp., *Spirifer pinguis* Sowerby, *Spirifer striata* Sowerby.

Spirifer horizon.—This is characterized by large numbers of the brachiopods, *Spirifer pinguis* and *Spirifer striata*. It occupies a high position in the Lower Burindi Series at O'Sullivan's Gap and may well be identical with Zone U. In

addition to the spirifers, the following forms were collected: "*Leptaena analoga*", *Chonetes* cf. *hardrensis*, *Fenestella* sp., *Productus* sp., Crinoid stems.

Gastropod horizon.—This may be of local occurrence. Only the one form, probably *Platyschisma depressa* Dana, was collected.

Tugrabakh Creek Limestone horizon (Zone T).—This horizon is characterized by the great abundance of crinoid stems and by the coral fauna—*Amygdalophyllum*, *Michelinia*, *Zaphrentis* sp., and *Syringopora* or *Cladochonus*. In associated mudstone the trilobite *Cordania gardneri* occurs.

The zones U, V, W and X were given the letters merely as a temporary device for reference purposes. Horizons within the zones are indicated by means of numbers, e.g. X1, X2, and X3. The letters have no other significance.

Sussmilch (1921, pp. 245–246) grouped all the marine fossils of the Upper and Lower Burindi and, in addition to some of those mentioned above, records *Dielasma sacculus*, *Orthis australis*, *Orthotetes crenistria*, *Spirifer crassa*, *Reticularia* and *Phillipsia* sp. indet.

Definite Lower Burindi forms, in addition to those included in that series, are *Gosseletina australis* Eth. fil., *Orthoceras* sp., *Bellerophon* sp., *Entolium* ?, *Cyrtina carbonaria* var. *australasica* Eth. fil., and *Monilopora nicholsoni* which come from Forster.

Devonian.

The Devonian rocks in the neighbourhood of Copeland were described by Sussmilch (1921, pp. 237–240). The same writer and W. N. Benson (1916) also examined and described the beds between Gloucester and Mount George, and agreed that representatives of the Tamworth and Barraba Series probably were present.

Reference to similar rock types was made by the writer (Voisey, 1938, 1939*a*, 1939*b*), but it has not been possible to separate the two series from one another up to the present time. Indeed, it is a matter of great difficulty to separate the Devonian from the Carboniferous strata.

Banded claystones and tuffs almost certainly belonging to the Tamworth Series are exposed by the Pacific Highway between Krambach and Brushy Mountain. Hard tuff bands are conspicuous in the series and have given rise to hilly country.

Between Krambach and Bunyah banded olive-green mudstones are interbedded with massive bluish-grey tuffs which, in places, outcrop as heaps of boulders which may be followed for some distance. Near Bunyah they have resisted erosion to the extent of forming parallel ridges running generally east and west. These rocks give way to those of Lower Carboniferous age between Bunyah and Gloucester.

The Devonian rocks extend eastwards to the margin of the coastal plains or lagoons. Evidence of their presence at the bridge over Wang Wauk river was demonstrated to the writer by Dr. G. D. Osborne in 1930. Dr. Osborne found *Lepidodendron australe* in the mudstones beside the bridge.

Conclusion.

The bearing which the geology of the Gloucester District has upon the study of the Upper Palaeozoic Stratigraphy of New South Wales will be discussed in a later publication. It is of interest to note that an increased number of marine fossils are now known from beds which are the equivalents of the terrestrial Lower Kuttung Series.

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List of References.

Benson, W. N., 1916.—The General Geology of the Gloucester District *J. Roy. Soc. N.S.W.*, l, p. xxxii.

Carey, S. W., 1934*a*.—The Geological Structure of the Werrie Basin. Proc. Linn. Soc. N.S.W., lix.

————, 1934*b*.—Report on the Geology of the Myall Lakes Region. *Science Journal*, Sydney University, 13, (3), p. 42.

————, 1937.—The Carboniferous Sequence in the Werrie Basin. Proc. Linn. Soc. N.S.W., lxii.

———— and Browne, W. R., 1938.—Review of the Carboniferous Stratigraphy, Tectonics and Palaeogeography of New South Wales and Queensland. *J. Roy. Soc. N.S.W.*, lxxii.

Carne, J. E., 1897.—Report on the Geology and Mineral Resources of the Coast between Port Macquarie and Cape Hawke. *A. R. Dept. Mines N.S.W.* for 1896.

David, T. W. E., 1932.—Explanatory Notes to a New Geological Map of the Commonwealth of Australia. Sydney.

Osborne, G. D., 1922.—The Geology and Petrography of the Clarencetown-Paterson Districts, N.S.W. Parts 1 and 2. Proc. Linn. Soc. N.S.W., xlvii.

————, 1929.—Some Aspects of the structural Geology of the Carboniferous Rocks in the Hunter River District between Raymond Terrace and Scone. Proc. Linn. Soc. N.S.W., liv (4).

————, 1937.—On Some Major Geological Faults North of Raymond Terrace and their Relation to the Structure of the Stroud-Gloucester Trough. *J. Roy. Soc. N.S.W.*, lxxi.

Sussmilch, C. A., 1921.—The Geology of the Gloucester District. *J. Roy. Soc. N.S.W.*, lv.

Voisey, A. H., 1938.—The Upper Palaeozoic Rocks in the Neighbourhood of Taree, N.S.W. Proc. Linn. Soc. N.S.W., lxiii.

————, 1939*a*.—The Upper Palaeozoic Rocks between Mount George and Wingham. Proc. Linn. Soc. N.S.W., lxiv.

————, 1939*b*.—The Geology of the Lower Manning District, N.S.W. Proc. Linn. Soc. N.S.W., lxiv.

EXPLANATION OF PLATE V.

Geological Map of the Country between the Manning and Karuah Rivers, N.S.W.

Note.—In the legend to the map, the Tugrabakh Creek Limestone is marked as Devonian in error. It should be Carboniferous.